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Two Large Dark Cloud Complexes in $l=351°$ to $1°$ and $b=-2°$ to $+2°$

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Abstract

Interstellar extinction within 4 kpc from the sun is investigated in the field of $351° \leq l \leq 1°$ through $l=0°$ and $|b| \leq 2°$ by means of the star-count method on the basis of the observed cumulative number and a space distribution model of late M giants. The general interstellar extinction in visual wavelengths is about 2.5 mag kpc^{-1} in the galactic plane and the scale height is about 100 pc in a distance range from 1.5 to 4 kpc from the sun for the distance, 10 kpc, of the sun from the galactic center. The space distribution analysis reveals two large dark cloud complexes associated with the spiral arms: one is around $l=352°$ and 2 kpc from the sun, and the other is around $l=359°$ and 3.2 kpc from the sun. The size of the complexes is about 300 pc in the direction of the galactic longitude, and the complexes may consist of many dark clouds.

Key words: Dark cloud complexes; Galactic structure; Interstellar extinction; M giants.

1. Introduction

The surface distribution of absorbing material can be seen on the atlases of dark clouds (Khavtasi 1960; Lynds 1968). Ichikawa et al. (1982a) have given a more detailed map of interstellar extinction with the limiting distance in $351° \leq l \leq 10°$ through $l=0°$ and $|b| \leq 2°$, which may be helpful in a search for small galactic windows.

The space distribution of interstellar extinction has been studied mainly on the basis of color excesses of early-type luminous stars (e.g. Neckel 1967; FitzGerald 1968; Lucke 1978; Neckel and Klare 1980). These data are, however, based on observations in visual wavelengths and are, therefore, restricted in the solar neighborhood. Moreover, early-type stars such as OB stars are at a disadvantage because of their inhomogeneous distribution in the galactic plane.

On the other hand, near-infrared observations of M giants are an efficient way to investigate intersteller extinction at considerable distance toward the galactic center (e.g. Hamajima et al. 1981, 1982; Ichikawa et al. 1982a). Late M giants are thought to be old objects so that they may represent the old stellar disk with an age of several times 10^9 yr. Therefore we can expect them to be more or less homogeneously distributed in the disk within a moderate scale height from the plane with a larger space density than that of OB stars.

Recently a survey of red giant stars has been carried out from $l=330°$ to $30°$ through $l=0°$ between $b=-2°$ and $2°$ (Ichikawa et al. 1982b). A catalog of M giants in a part of the survey field has been published (Raharto et al. 1984). Using the catalog, we can investigate the space distribution of interstellar extinction in the field of $351° \leq l \leq 1°$ and $|b| \leq 2°$.

2. Observational Material

2.a. *Basic Stars*

We take *A Catalogue of M Type Stars* (Raharto et al. 1984) as the basic material. The catalog lists 2116 M-type stars in a range from $l=351°$ to $1°$ and $|b| \leq 2°$.

Early M-type stars (M0–M4 spectral type) were excluded from the present analysis because of the distance modulus smaller than that of late M-type stars (M5–M8 spectral type) and because of possible contamination by young populations residing in the spiral arms (e.g. Mavridis 1971; Ichikawa 1981).

Late M-type stars in $351\overset{\circ}{.}0 \leq l < 354\overset{\circ}{.}5$, $354\overset{\circ}{.}5 \leq l < 357\overset{\circ}{.}5$, and $357\overset{\circ}{.}5 \leq l \leq 1\overset{\circ}{.}0$ are extracted from tables 4, 5, and 6 of the catalog, respectively, in order that the common stars listed in different tables may not be counted twice.

The slight systematic differences of the spectral classification among the tables are negligible in the present analysis. A total of 1084 late M stars are used as the basic data; these stars can all safely be assumed as giant stars (Ishida and Mikami 1982).

2.b. *Apparent I Magnitudes and R−I Colors*

The catalog lists apparent I magnitudes and $R-I$ colors on Kron's system (Kron and Smith 1951; Kron et al. 1953). Raharto et al. (1984) reported, however, zero point errors in the I and R magnitudes both between their fields nos. 8 and 9 and between nos. 9 and 10. We examined the errors, using the members of open cluster Pismis (1959) 24 which is located at $l=353\overset{\circ}{.}1$, $b=+0\overset{\circ}{.}7$ in field no. 8. Neckel (1978) obtained photoelectrically I_J magnitudes and $(R-I)_J$ colors of the members on the Johnson system; these magnitudes are listed in the second and third columns of table 1. Using the transformation relation from the Johnson system to Eggen's (1971), we can derive them on Eggen's (1971) system (the fourth and fifth columns). Kron's I system adopted in the catalog is considered to be the same system as Eggen's (1971). The last two columns of table 1 give the present magnitudes and colors obtained with the same calibration method used by Raharto et al. (1984). Although it is hard to comment on the very different result for no. 47, the other results coincide well within the error of their photometry. Therefore we consider that the empirical method adopted by Raharto et al. (1984) has no serious zero point errors in field no. 8.

The I magnitudes in field no. 9 are systematically fainter than in the contiguous fields by about 0.2 mag on average. Regarding I magnitudes of fields no. 8 and no. 10 as correct, we subtracted those of the stars in field no. 9 by 0.2 mag. Inherently, M giants have large dispersions of about 0.7 mag in the absolute magnitude. Therefore, a small

Table 1. A comparison of I magnitudes and $R-I$ colors for the members of open cluster Pismis (1959) 24.

No.*	I_J	$(R-I)_J$	I_E	$(R-I)_E$	$I_{present}$	$(R-I)_{present}$
38	9.25	1.25	9.93	0.95	9.90	0.91
40	12.14	0.70	12.71	0.51	12.62	0.40
42	11.07	1.25	11.75	0.95	11.94	0.92
43	10.23	1.24	10.91	0.94	11.00	0.91
46	9.70	1.11	10.43	0.84	10.53	0.79
47	12.34	0.73	12.92	0.53	12.42	0.20

* The numbers are taken from Neckel (1978).

error in the I magnitude can be ignored. Since we gave no corrections to the R magnitude, the $R-I$ colors may be less reliable.

3. Distribution of Color Excesses

One of direct ways to get detailed information on interstellar extinction is an analysis of color excess E_{R-I} and distance r of individual M giants. Visual extinction A_V can be obtained from

$$A_V = 4.3 E_{R-I} \,, \tag{1}$$

where the total-to-selective extinction 4.3 is derived by the reddening curve No. 15 of van de Hulst [1949; quoted in Johnson (1968)]. The distance modulus is then given by

$$I - M_I - 0.5 A_V = 5 \log r - 5 \,. \tag{2}$$

In this relation, the interstellar extinction in the I band is assumed to be a half of the V band.

For late M giants, the absolute magnitude M_I in the I band is obtained from the visual

Table 2. Assumed absolute magnitudes and intrinsic colors of late M giants.

Physical quantity	Spectral type					
	M5	M6	M6.5	M7	M8	M9
M_V	−0.7	−0.3	(+0.1)	+0.5:	+1.5:	
$(V-I)_0$	3.02	3.46	(3.75)	4.03	4.7:	5.4:
M_I	−3.7	−3.8	(−3.7)	−3.5	−3.2	
$(R-I)_0$	1.5	1.7	(1.8)	(1.9)	(2.1)	

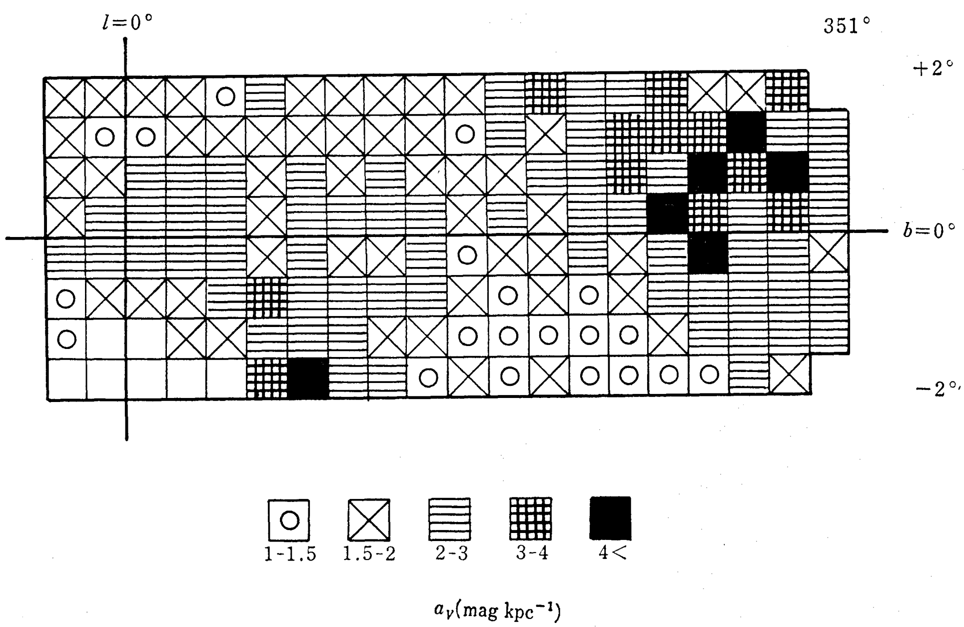

Fig. 1. The surface distribution of interstellar extinction given by Ichikawa et al. (1982a) for the present region.

absolute magnitude M_V given by Mikami and Heck (1982) with the intrinsic colors $(V-I)_0$ of Blanco (1964). The intrinsic colors $(R-I)_0$ on Kron–Eggen's system are transformed from the values of Lee (1970) on the Johnson system with a relation given by Eggen (1971). These values are listed in table 2, where the values in parentheses are assumed from their results.

The surface distribution of the absorbing material given by Ichikawa et al. (1982a) is reproduced in figure 1 for the present region. At a glance, the interstellar extinction is found to vary much in the region; a large dark cloud with strong extinction prevails around $l=352\overset{\circ}{.}5$, $b=+1°$ and very transparent region or the so-called window around $l=354\overset{\circ}{.}5$, $b=-1.5$.

Using I magnitudes and $R-I$ colors of the catalog, we obtain A_V and r for each star from equations (1) and (2) with M_I and $(R-I)_0$ in table 2. The results are shown in figure 2 for three representative regions. The stars with an uncertain spectral type or with an inaccurate magnitude or color are excluded from this analysis.

About only one third of the cataloged stars can be used for the present analysis mainly because the remaining ones are so faint in the R magnitude that there are no data on $R-I$ colors in the catalog even though the I magnitude is given. The solid curves in figure 2 indicate the limiting distance of the analysis which is defined by the brightest and faintest stars in the R magnitude of the catalog.

The accuracy of the color excess depends on that of the photometry of $R-I$ colors and on the determination of the intrinsic colors. The error in $R-I$ is considered to be about 0.4 mag. The error 0.7 subclass of the spectral classification in the catalog leads

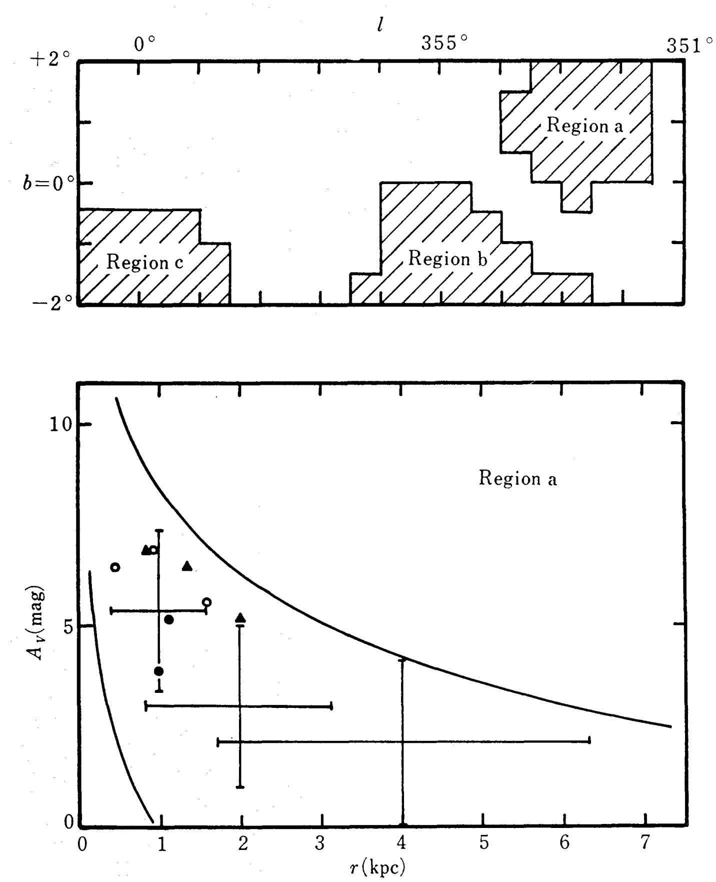

Fig. 2. See the legend on the next page.

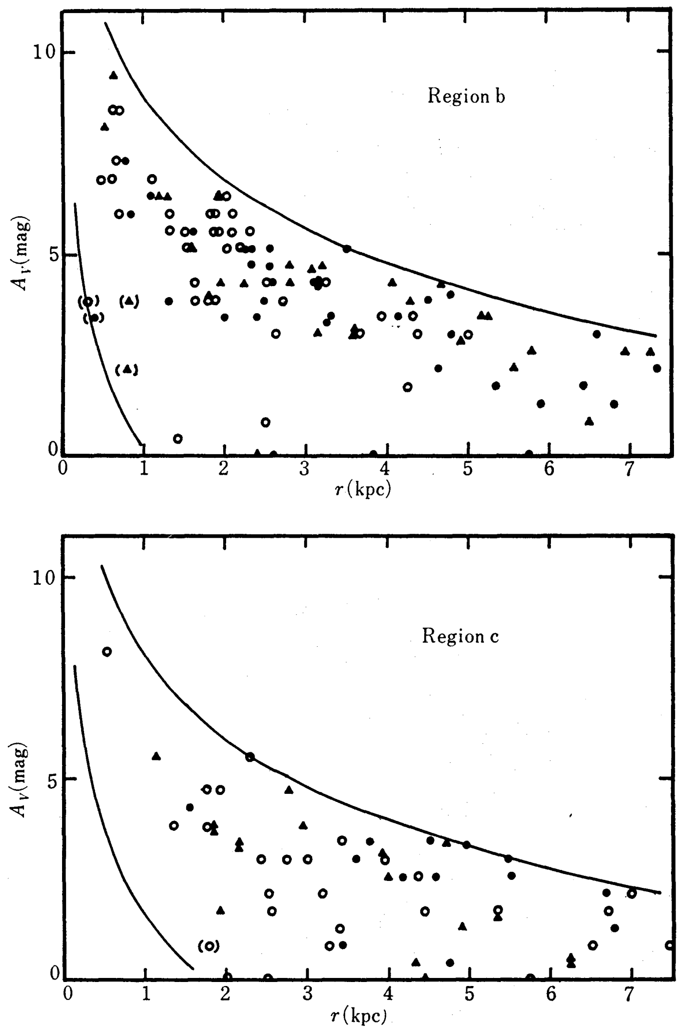

Fig. 2. Interstellar extinction A_V in visual wavelengths versus distance r from the sun for M5 (filled circles), M6 (filled triangles), and M6.5 or later spectral-type giants (open circles) in three representative regions. The standard errors in A_V and r are shown at several distances. The solid curves represent the limiting distances defined by the brightest and faintest stars in the R magnitude of the catalog. The symbols in parentheses indicate uncertain determinations.

to an error of about 0.2 mag in the estimate of the intrinsic color. As a result, a standard error of about 2 mag is expected in A_V. The accuracy of r depends on the dispersion $\sigma=0.7$ mag of the absolute magnitude, the error 0.3 mag in the I magnitude, and the error 2 mag in A_V. The derived error in r is roughly 60%. The error bars for both A_V and r at several distances are shown in a part of figure 2.

The absorbing material may be recognizable by the fact that A_V is higher behind a cloud than in front of it. The scatter in figure 2 is, however, too large to look for the variation of A_V with increasing distance. This large scatter may not be due to the real variation of the interstellar extinction in the region, since no change can be seen in the tendency even if smaller regions are chosen, but it may be due to the large errors in A_V and r.

Although we cannot get detailed information on interstellar extinction from figure 2 for the reasons of the large scatter and the small limiting distance of the analysis, it is suggested that a strong absorbing material is located around at 1 kpc in region a, while region c is most transparent.

4. Model Calculation

The analysis of the distribution of color excess may be unsuited for the present study, because many faint M-type stars have no color data. Moreover, figure 2 disadvantageously shows a large scatter in the distribution. Therefore we use here an assumed space distribution model of M giants.

The analysis follows that of Mikami and Ishida (1981) and Mikami et al. (1982). The cumulative number of stars $N(I)$ brighter than apparent I magnitude is the basic data in the present analysis. It is calculated from a space distribution model of late M giants, $n(r, l, b)$, in the direction of the galactic coordinates (l, b) at the distance r kpc from the sun, and the Gaussian luminosity function $\phi(M)$ with the following formulae:

$$N(I)=\int_{-\infty}^{I}\int_{l_1}^{l_2}\int_{b_1}^{b_2}\int_{0}^{\infty} rn(r, l, b)\phi(M)\, drdbdldm \ , \quad (3)$$

$$M=I+5-5\log r-\int_{0}^{\infty} 0.5a_V(r, l, b)dr \ , \quad (4)$$

$$\phi(M)=(1/\sqrt{2\pi}\,\sigma)\exp\left[-(M-\langle M\rangle_I)^2/2\sigma^2\right] . \quad (5)$$

We adopt the mean absolute magnitude $\langle M\rangle_I=-3.7$ for all late M giants as in Ichikawa et al. (1982a), but with a little modification following the result of Mikami and Heck (1982).

The space density $n(r, l, b)$ is expressed by the following formulae in the space volume concerned in the present field:

$$n(r, l, b)=n_0\exp\left[-(R-R_\odot)/R_e\right]\exp(-Z^2/2Z_e^2) \ , \quad (6)$$

$$R^2=r^2\cos^2 b+R_\odot^2-2rR_\odot\cos b\cos l \ , \quad (7)$$

$$Z=R\sin b \ , \quad (8)$$

where R and Z are the distances from the galactic center and from the galactic plane, $R_\odot$ the distance to the sun from the galactic center, n_0 the space density in the solar neighborhood, R_e the scale radius of the galactic disk, and Z_e the scale height of the disk. Mikami and Heck (1982) have revised the aboslute magnitude of late M giants. Since the mean magnitude has been found to be brighter than Mikami's (1978) value by an amount of 0.3 mag for late M giants in visual wavelengths, n_0 should be lower than that obtained by Mikami and Ishida (1981), which is based on Mikami's (1978) value. Therefore we adopt $n_0=1.1$ stars per 10^{-6} pc^3. The dispersion of the absolute magnitude is assumed to be $\sigma=0.7$ mag.

We adopt first $R_e=2.3$ kpc and $Z_e=390$ pc for $R_\odot=10$ kpc (Mikami et al. 1982). The space distribution model of late M giants, however, depends on the distance to the sun from the galactic center. The model used here is based on those by Maihara et al. (1978) and Mikami et al. (1982). Following their models, the case of $R_e=1.6$ and 2.0 kpc are also examined for $R_\odot=7$ kpc (e.g. Frenk et al. 1982) and 8.5 kpc (e.g. Harris 1980), respectively, with the same $Z_e=390$ pc.

We assume a stratified absorbing material as expressed by the following formula:

$$a_V(r, l, b)=a_0 \exp(-|Z|/Z_0)\,, \tag{9}$$

where a_0 is the interstellar extinction in visual wavelengths at the galactic plane $b=0°$ in units of mag kpc^{-1} and Z_0 is the scale height. The numerical parameters to be assumed here are a_0 and Z_0.

The absorbing material is closely related to CO clouds. Robinson et al. (1983) presented the result for a well sampled survey of J=1–0 ^{12}CO line emission along the southern galactic plane in a range of $294° \leq l \leq 358°$, $|b| \leq 0.^{\circ}075$. Although the distribution of the CO line emission shows spiral arm structure, we do not take account of it in the model (9), because CO clouds are found to be rather patchily distributed. The absorbing material locally distributed in our investigated region will be shown by the following analysis as a deviation from the general interstellar extinction model (9). Comparison of our result with the distribution of CO line emission will be made in section 6.

Calculated cumulative numbers $N(I)$ are shown in figures 3a and 3b in the case of $R_{\odot}=10$ kpc for several sets of a_0 and Z_0. In the calculation, the field of $358.^{\circ}5 \leq l \leq 1°$ and $-2° \leq b < -1.^{\circ}25$ are excluded since the completeness of the survey in the field may be less than those of other fields due to image overlaps [see Raharto et al. (1984)].

5. Space Distribution of Interstellar Extinction

5.a. log $N(I)$–I Diagrams

Variations of the observed cumulative number of late M giants in the whole region are shown in figure 3. The stars with uncertain spectral classification are included in the number since their true spectral types may not deviate largely from the bin of M5–M8. As compared with the observational result, the model in the case of a_0=2.5 mag kpc^{-1}

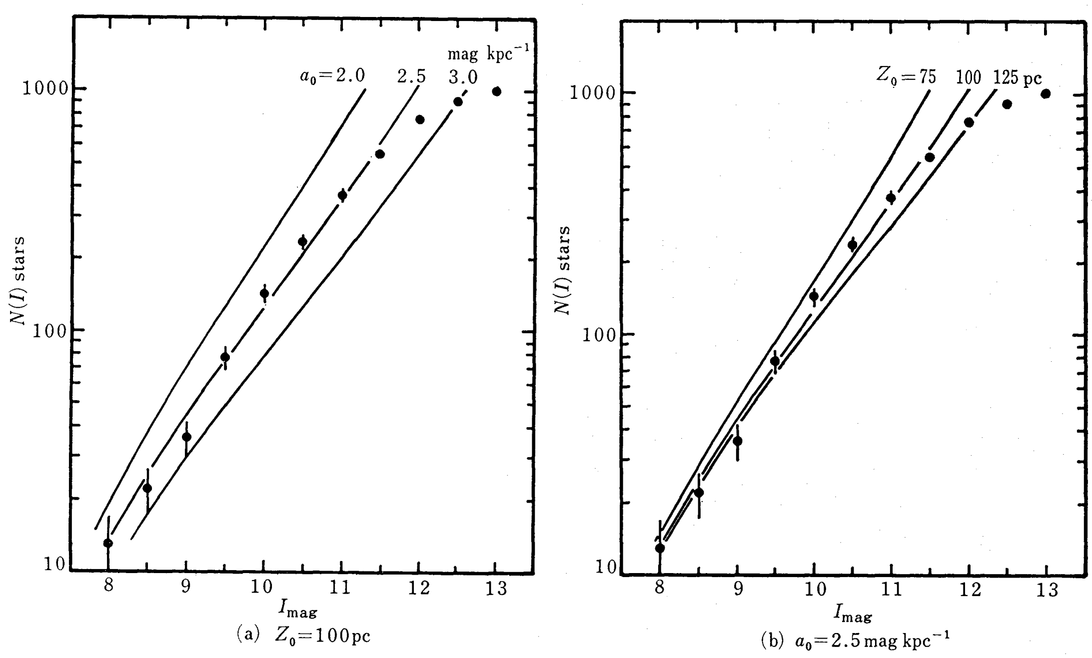

Fig. 3. Cumulative number $N(I)$ versus apparent I magnitude, in $351° \leq l \leq 1°$ and $|b| \leq 2°$, but the field of $358.^{\circ}5 \leq l \leq 1°$ and $-2° \leq b < -1.^{\circ}25$ is excluded. Filled circles with standard error bars stand for the observation. The solid curves in figures show the models (a) of a_0=2.0, 2.5, and 3.0 mag kpc^{-1} with Z_0=100 pc and (b) of Z_0=75, 100, 125 pc with a_0=2.5 mag kpc^{-1}.

and $Z_0=100$ pc is best fitted to the observation for $R_{\odot}=10$ kpc. Since the investigated region is restricted near the galactic plane of $|b|\leq 2°$, Z_0 is difficult to be accurately determined.

In the case of $R_{\odot}=7.0$ and 8.5 kpc, the best-fitted models are $a_0=2.9$ and 2.7 mag kpc^{-1} with $Z_0=100$ pc, respectively. In the following discussion, we will consider only the case of $R_{\odot}=10$ kpc since the change of $R_{\odot}$ does not seriously affect the following discussion.

Figure 4 compares the observed cumulative number in the window and the dark cloud region with the model obtained above.

5.b. (r, l) Distribution

In order to present the result in a more useful form and to emphasize the three dimensional aspect of the distribution of interstellar extinction, we examine the spatial distribution in the (r, l) plane for three intervals of Z. In order to investigate the absorbing material locally distributed, the deviation Δa_0 from the general model is calculated in each direction. We use here only the stars brighter than 12.5 mag.

The dispersion $\sigma=0.7$ mag in the absolute magnitude results in an error of 32% in the distance, and therefore may result in an elongated spatial structure. The size of the dark cloud thus obtained may have less information in the direction of r. For that reason, we adopt elongated bins in the r direction for the determination of the spatial distribution. We divide the investigated space into bins with a size of about 90 to 150 pc in l, 50 to 100 pc in b, and 500 pc in r so that 10 stars or more are contained in each bin. The bin size of l and b directions depends on r. Figure 5 shows the result of Δa_0 for three bins of Z. We combine figures 5a–c into figure 6 in order to examine the overall distribution of the absorbing material.

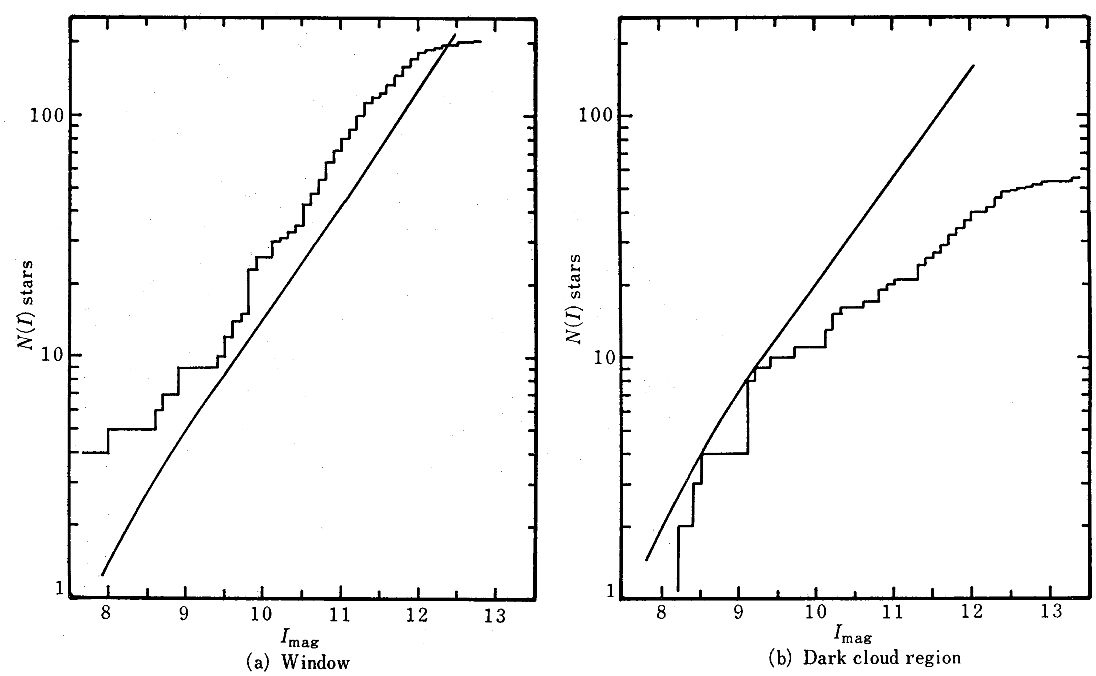

Fig. 4. The observed cumulative number (a) in the window from $l=353°.5$ to 356° between $b=-2°$ and $-0°.5$ and (b) in the dark cloud region from $l=351°.5$ to 354° between $b=-0°.5$ and $+2°$. The observations are compared with the model expressed by the solid curves in the case of $a_0=2.5$ mag kpc^{-1} and $Z_0=100$ pc.

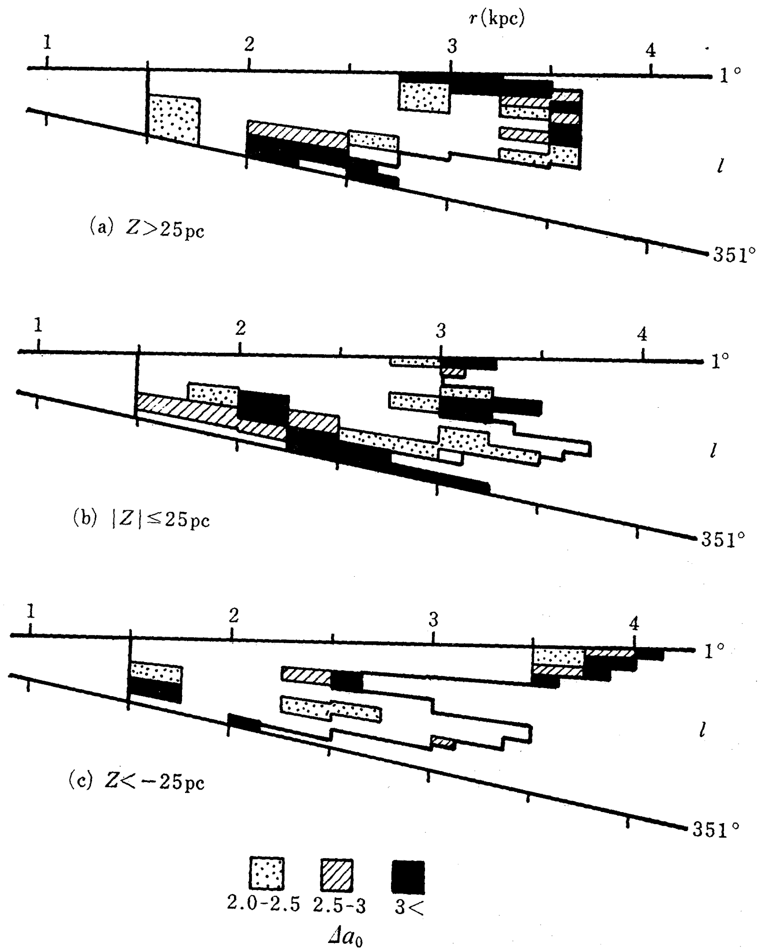

Fig. 5. Spatial distribution of interstellar extinction in (l, r) plane within $|b| \leq 2°$ for (a) $Z > 25$ pc, (b) $|Z| \leq 25$ pc, and (c) $Z < -25$ pc. Dotted, hatched, and filled regions have the interstellar extinction larger than the general model in the case of $a_0 = 2.5$ mag kpc^{-1} and $Z_0 = 100$ pc by an amount of $\Delta a_0 = 2.0$, 2.5, and 3.0 mag kpc^{-1}, respectively.

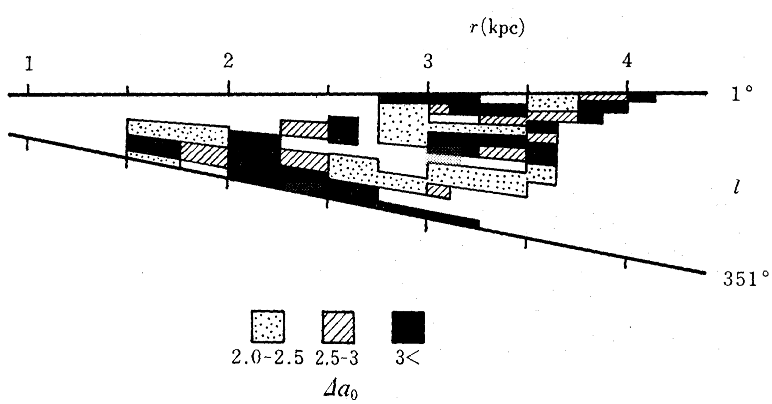

Fig. 6. Combined spatial distribution of the interstellar extinction. Figures 5a–c are projected on to the galactic plane.

The inner edge for the analysis at 1.5 kpc from the sun in figure 5 is defined by a very small number of inner stars. On the other hand, the outer edge is defined in each direction by a limiting magnitude of 12.5 mag.

5.c. *Accuracy of the* (r, l) *Distribution*

The (r, l) distribution obtained above may be affected by two things. One is the inhomogeneity of the assumed space distribution of late M giants, and the other is the possible incompleteness of the catalog.

If late M giants were not distributed homogeneously as in the general model, our result would be affected. Late M giants are considered to be old objects so that they may be well mixed in the galactic disk. Therefore the inhomogeneity is considered to result from statistical error of the star number. Since each bin used in section 5a contains at least 10 stars, the standard error is at most about 32% of the number. We examine the effect of the 32% error in n of equation (3). As a result, it is found that the error causes the fluctuation of about 1.0 mag kpc^{-1} in Δa_0. The dotted regions in figures 5 and 6 have Δa_0 larger than 2.0 mag kpc^{-1}, which is well above the standard error. Therefore, the confidence of figures 5 and 6 is good.

Figure 3, however, suggests the incompleteness of the catalog near the limiting magnitude. The observed cumulative number agrees well with the best-fitted model up to 11 mag, but deviates gradually from the model with increasing magnitude. The deviation at 11.5 mag is only 10% of the star number expected from the model. It reaches 28% at 12.0 mag and 51% at 12.5 mag.

Figure 4 indicates completeness as faint as 12.0 mag in the window and 12.6 mag in the dark cloud region. The difference of the completeness depending on the field is probably correct. In more transparent regions, more stars come into view on plates, and therefore, faint stars are apt to be hidden by nearby bright stars. No incompleteness is, however, suggested in figure 4 at 11.5 or 12.0 mag.

Sometimes strong absorbing material defines the limiting distance of the detection because stars behind them are blocked out. In that case the observed cumulative number may deviate more largely with increasing magnitude especially near the limiting magnitude. This tendency can be seen in the dark cloud region of figure 4b. Therefore a strong absorbing material near the limiting magnitude probably causes the deviation from the model seen in figure 3.

The possibility of incompleteness in the catalog may, however, still remain. Even if it is real, the 28% incompleteness does not seriously change the aspect of figures 5 and 6, since it is less than the standard error of the space distribution model of M giants discussed above. As the deviation at 12.5 mag is much larger than the standard error, the reliability of figures 5 and 6 near the limiting distance may be less in that case.

In any case, since figures 5 and 6 are derived only with the stars brighter than 12.5 mag, the confidence in the result is safely considered to be well above the standard error except for the places near the respective limiting distances.

6. Discussion

6.a. *Overall Distribution*

Our result of general interstellar extinction is expressed by $a_0=2.5$ mag kpc^{-1} in visual wavelengths and $Z_0=100$ pc at $b=0°$ in $351° \leq l \leq 1°$ and $|b| \leq 2°$ and in a distance range from $r=1.5$ to 4 kpc from the sun. It can be compared with Sharov's (1964) result of $a_0=$ 1.9 mag kpc^{-1} and $Z_0=58$ pc in his region no. 96, which is nearly the same direction as of ours. He obtained the result from the data on only 33 stars located up to distance $r=$ 1.9 kpc from the sun. As the space volume of the galactic disk studied by Sharov (1964) is not necessarily common with ours, it is hard to comment on the discrepancy in a_0 and Z_0 thus derived.

Color excess distributions in the galactic plane out to 2 or 3 kpc from the sun have been given by many authors (e.g. Neckel 1967; FitzGerald 1968; Lucke 1978; Neckel and Klare 1980). The dust cloud found by FitzGerald (1968), extending from $l=350°$ to 0° between 1.2 and 1.7 kpc from the sun, is located at 1 kpc in a map of Neckel and Klare (1980), but does not show up on a map of Lucke (1978). Although the general aspect of the color excess distribution agreesw ell among the results by many authors, the local distributions with a size of several hundred parsecs such as our investigated region vary much. The variance may be ascribed to the samll numbers of the stars used for their study.

6.b. *Large Dark Cloud Complexes*

Two large dark cloud complexes with a size of several hundred parsecs stand out in figure 6 around $l=352°$ at 2 kpc from the sun and around $l=359°$ at 3.2 kpc. Hereafter we call these complexes LDC 1 and LDC 2, respectively, for convenience. LDC 1 has extremely heavy extinction which blocks out most of stars behind it. Assuming the ratio of the column density of molecular hydrogens to interstellar extinction, $N(H_2)/A_V=0.94\times 10^{21}$ molecules cm^{-2} mag^{-1} (Frerking et al. 1982), we can rounghly estimate the masses of LDC 1 and LDC 2 to be $M_{H_2}=1.2\times10^6 M_\odot$ and $9.8\times10^5\,M_\odot$, respectively. Since the present investigation does not see through the whole dark cloud complexes, the total masses are probably larger. Both complexes seem to be composed of a number of somewhat smaller dark clouds as suggested by the masses, the sizes, and the distributions.

Hodge (1980) compared the size distribution of the dark clouds in the Galaxy, LMC, and M31. The sizes of the M31 sample range from 15 pc to 2.3 kpc. The largest dark cloud complex in the Galaxy is observed in the solar vicinity between $l=340°$ and 150° and extends up to 1 kpc from the sun (FitzGerald 1968; Neckel and Klare 1980). Neckel (1967) and FitzGerald (1968) found that dark clouds in the Galaxy vary from 100 pc to 1 kpc in diameter. Therefore large dark cloud complexes with a size of LDC 1 and LDC 2 probably exist.

In addition we comment on star forming regions around LDC 1. In its vicinity, there are several young open star clusters: Ruprecht 127 at $(r, l, b)=(1.53$ kpc, $352\overset{\circ}{.}9$, $-2\overset{\circ}{.}4)$ [quoted in Alter et al. (1961)], Bo 13 at (1.7 kpc, $351\overset{\circ}{.}2$, $+1\overset{\circ}{.}4$) (Moffat and Vogt 1975), and a very strongly reddened OB star cluster, Pismis (1959) 24 at (2.09 kpc, $353\overset{\circ}{.}1$, $+0\overset{\circ}{.}7$) (Moffat and Vogt 1973) which may be inside of LDC 1. H II regions, NGC 6334 at (1.7 kpc, $351\overset{\circ}{.}2$, $+0\overset{\circ}{.}5$) and NGC 6357 at (1.74 kpc, $353\overset{\circ}{.}3$, $+0\overset{\circ}{.}8$) (Neckel 1978), are located near the edge of LDC 1 on the side of the sun. Very extended H166α emission is also observed in $l=348°$ to 357° with a notable peak at $l=352\overset{\circ}{.}5$ (Hart et al. 1983). CO observations near NGC 6334 made by Dickel et al. (1977) revealed the presence of an elongated giant molecular cloud of total mass of $\sim10^4 M_\odot$. A considerable number of compact sources are embedded in the cloud and active star formation is indicated [see Persi and Ferrari-Toniolo (1982) and references therein]. These observations suggest that LDC 1 is correlated with active star formation.

6.c. *Comparison with Far-Infrared and CO Line Emissions*

Studies of galactic far-infrared and CO line emissions relate directly to the distribution of dust in the Galaxy. The galactic diffuse far-infrared emission has been observed by balloon-borne telescopes, giving a surface brightness distribution along the galactic plane (Maihara et al. 1979; Nishimura et al. 1980). Some emission peaks tend to coincide with the location of LDC 1 and LDC 2. Three prominent discrete sources No. 1 (352°.3, −0°.1), No. 2 (353°.2, +0°.3), and No. 3 (356°.0, +0°.0) given by Nishimura et al. (1980) are probably correlated with LDC 1. These sources also coincide with those of limited CO observations at $b=0°$ by Burton and Gordon (1978). The bulk of the far-infrared emission strongly concentrated to the galactic center direction is attributed to the dense dust in the innermost region of the Galaxy, such as Sgr A and Sgr B2 (Nishimura et al. 1980). The majority of emission from LDC 2 may be hidden by that from the dust. The source No. 4 (357°.5, +0°.1) of Nishimura et al. (1980), however, is located near the edge of LDC 2.

Robinson et al. (1983) presented a position-velocity map of ^{12}CO line emission in a wide region along the southern galactic plane in $|b| \leq 0°.075$. A very compact CO cloud stands out at $l=348°$ and $351°$ with a radial velocity range from about −10 to −4 km s^{-1} in their figure 1. The latter cloud seems to be a part of the large CO cloud observed by Dickel et al. (1977) at $l=351°.5$, $b=+0°.6$ near the H II region, NGC 6334. Another notable but diffuse CO cloud which may also be correlated with LDC 1 prevails over from $l=352°$ to 355° with a radial velocity range from −5 to +5 km s^{-1}. Taken into account of the spread of both observed CO line emission and far-infrared emission regions, LDC 1 may extend to $l=348°$ and therefore have a size of about 600 pc in l direction.

On the other hand, the majority of the CO line emission from LDC 2, if any, would be overwhelmed by brighter sources in the galactic center region, so that it is hard to comment on CO clouds which might be correlated with LDC 2.

6.d. Correlation with Spiral Arms

LDC 1 and LDC 2 seem to be associated with spiral arms on the galactic center side of the sun. The location of LDC 1 reasonably fits that of the Sagittarius arm defined by optical spiral arm tracers (e.g. Humphreys 1976; Fenkart and Binggeli 1979) and by H I gas (e.g. Davies 1972). In the direction of $l=0°$ at distances from 3 to 4 kpc, the line of sight appears to cross another spiral arm called the Norma-Scutum arm interior to the Sagittarius arm (Humphreys 1976). LDC 2 may reside in this arm.

6.e. Galactic Window

Although it is hard to comment quantitatively, region c in figure 2 is most transparent in the present field. Figure 2 shows that the intersteller extinction remains to be about $A_V=2.5$ mag to 5 kpc from the sun or farther. This region is considered to form a part of the Sagittarius star cloud A which contains three well-known galactic windows (van den Bergh 1968).

The surface brightness of the diffuse far-infrared emission near $l=355°$ is extraordinarily low. The region of about $2° \times 1°$ around $l=355°$ and $b=-1°$ shows an anomalous enhancement of the infrared diffuse radiation at $\lambda=2.4$ μm (Oda et al. 1979). Both phenomena are understood in terms of a deficiency of the absorbing material along this direction (Hamajima et al. 1981; Ichikawa et al. 1982a). Hamajima et al. (1981) showed that M giants located in the 2.4-μm enhanced region have lower extinction than that in the comparison region at $l=357°$, $b=-1°$ by about $A_V=1.8$ mag in average. Figure 4a supports their conclusion even in a wider field. The observed cumulative number of late M giants in figure 4a is 1.5 to 2 times larger than that of the general extinction model from 10 to 12 mag. With respect to the interstellar extinction, the window has smaller extinction by about $A_V=1$ mag in the same range. Hamajima et al. (1981) concluded, comparing the surface brightness of 2.4-μm radiation with the surface number density of M giants, that the window extends beyond $r=4.6$ kpc.

These galactic windows would be important for further investigation of the inner galactic structure.

7. Summary

The space distribution of interstellar extinction in a range from 1.5 to 4 kpc from the sun is investigated in $351° \leq l \leq 1°$, $|b| \leq 2°$. The general interstellar extinction in visual wavelengths is about $a_0=2.5$ mag kpc^{-1} at $b=0°$ with a scale height of $Z_0=100$ pc in the case of $R_\odot=10$ kpc. For $R_\odot=7.0$ and 8.5 kpc, the best-fitted models with the observation are $a_0=2.9$ and 2.7 mag kpc^{-1} with $Z_0=100$ pc, respectively.

Two large dark cloud complexes stand out around $l=352°$ and 2 kpc in the Sagittarius spiral arm and around $l=359°$ and 3.2 kpc in the Norma-Scutum spiral arm with a size of about 300 pc and with a mass M_{H_2} larger than $10^6 M_\odot$. These complexes may consist of many small dark clouds. The former one is well correlated with CO clouds, far-infrared radiation, and the star forming region. Taken into account of the observations of CO line emission and far-infrared emission, this complex may extend to $l=348°$ with a size of about 600 pc in the direction of the galactic longitude.

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